Feasibility of Non-Proprietary Ultra-High Performance Concrete (UHPC) for Use in Highway Bridges in Montana: Implementation

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UHPC Project Background

- Phase 1 – Feasibility
  - We can make UHPC with materials readily available in Montana
- Phase 2 – Field Application and Sensitivity Study
  - Changes in constituent materials and batch size
  - Bonding properties and pull-out strengths
- *Concurrent Proposed Project - Applications*

Project Scope

Task 1 – Literature Review

Task 2 – Close Minor Research Gaps

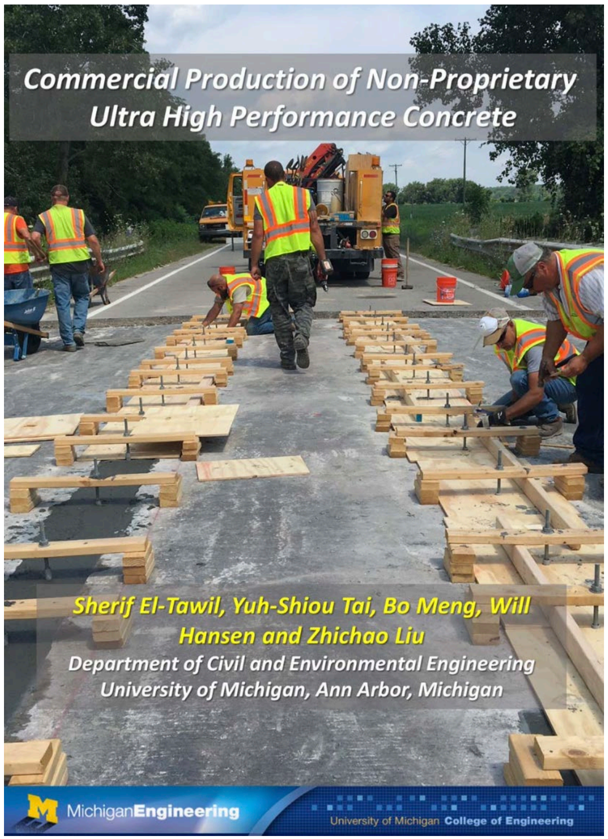
Task 3 – Bridge Construction and Related Activities

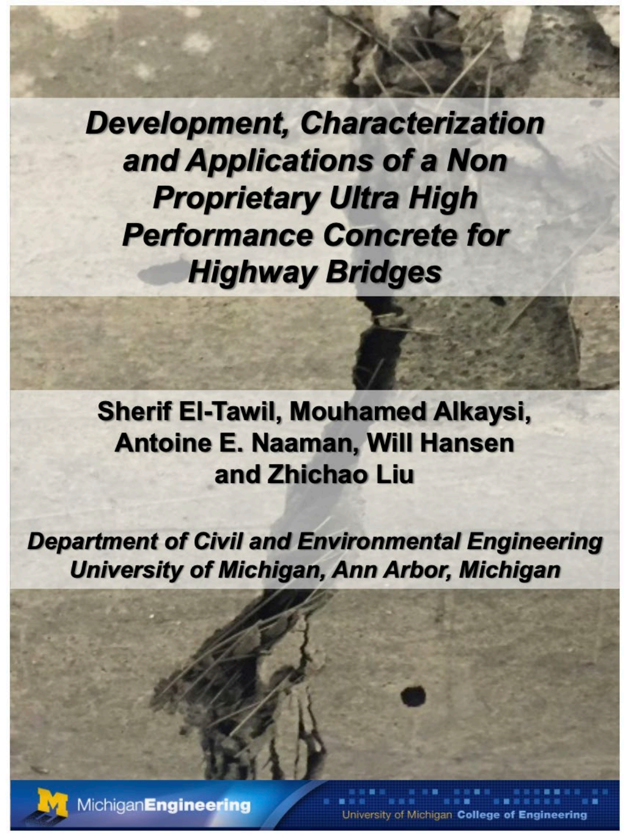
Task 4 – Monitor Bridge Performance

Task 5 – Analysis of Results and Reporting

Task 1 - Literature Review

Perform a review of recent research related to UHPC Implementation.

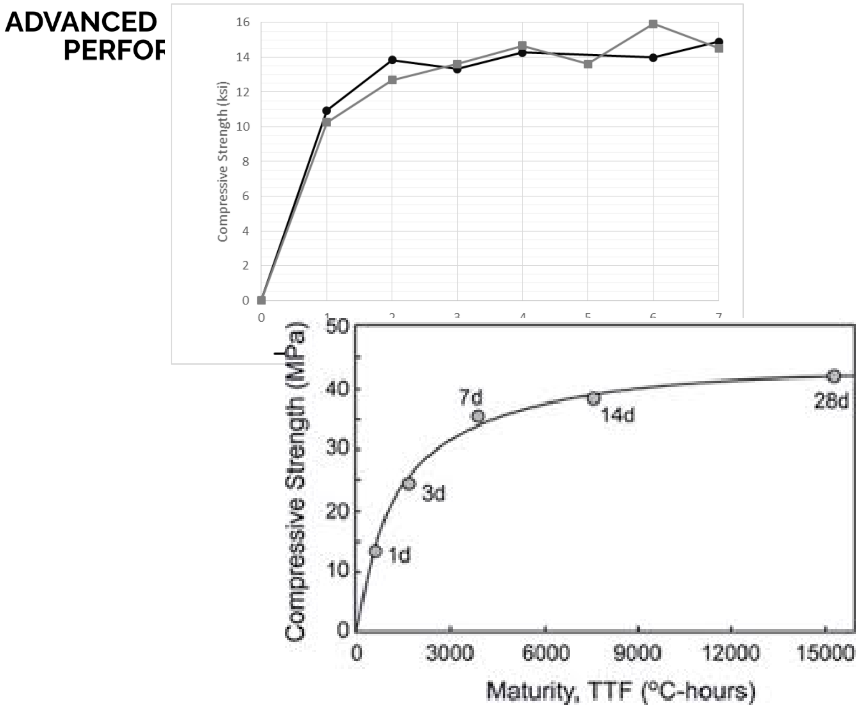




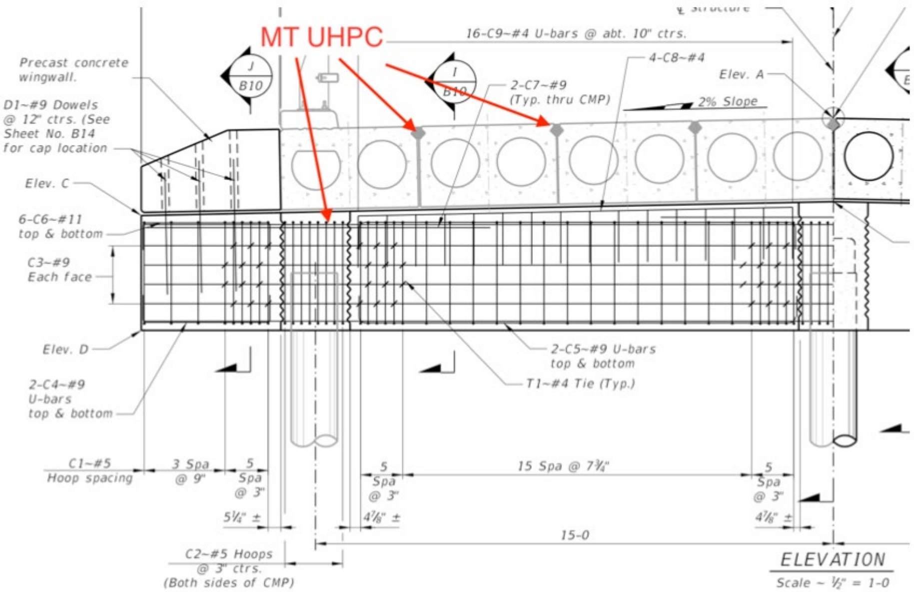
Task 2 – Close Minor Research Gaps

- Confirm Performance of Buy America Acceptable Steel Fibers
- Refined Strength Gain Profile
- Maturity Curve Including Early Strength Gain

HIPER FIBER



Task 3 – Bridge Construction and Related Activities



Task 3 – Bridge Construction and Related Activities

- Development of specifications, mix designs, and mixing procedures

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Montana UHPC Materials and Mixing

Ultra-high performance concrete (UHPC) has mechanical and durability properties that far exceed those of conventional concrete. Thus, elements made with UHPC are smaller and lighter than elements made with conventional concrete. The enhanced durability properties of UHPC also allow for longer service lives and decreased maintenance costs. However, using UHPC in conventional concrete applications has been cost prohibitive, with commercially available/proprietary mixes costing over 20 times conventional concrete mixes. Recent research at Montana State University has focused on the development and evaluation of nonproprietary UHPC mixes made with materials available in Montana [1, 2]. This document is intended to provide guidance on the requisite materials for the Montana UHPC, and to outline its mixing and placing procedures. It should be noted that this document is intended for estimating purposes, to provide a feel for what the material/process entails. Trial batches, fine tuning, and a bit of practice will be required before its use in the field.

If you have any questions/concerns feel free to contact the researchers directly -- Michael Berry (berry@montana.edu) and Kirsten Matteson (kirsten.matteson@montana.edu).

Materials

The requisite materials for making the Montana UHPC are water, portland cement, fly ash, silica fume, high range water reducer, steel fibers, and fine aggregates. The material weights for 1 cubic yard of the Montana UHPC are provided in Table 1.

Table 1: UHPC Mix Design (1 cy)

Item	Amount (lbs)
Water	298.7
Portland Cement	1299.5
Fly Ash	371.3
Silica Fume	278.4
HRWR	64.4
Steel Fibers	262.9
Fine Aggregate	1556.4

While other material sources were investigated as part of MSU's research, the material sources studied the most in their research are documented in Table 2, along with the contact information for the suppliers. For more specifics on the materials, please refer to the references at the end of this document.

Table 2: Montana UHPC Materials

Material	Type	Supplier	Contact	email
Portland Cement	Type I/II	GCC Trident Cement Plant	Bryan Patterson	bpatterson@gcc.com
Fly Ash	Class F	GCC Trident Cement Plant	Bryan Patterson	bpatterson@gcc.com
Silica Fume	MasterLife SF 100	BASF	Brett Bermingham	brett.bermingham@mbcc-group.com
High Range Water Reducer	CHRYSO Fluid Premia 150	Chryso Inc.	Taylor James	taylor.james@chrysoinc.com
Steel Fibers	Type A: Straight Steel Fibers	HiPer Fiber Solutions	Andrew Tai	sales@hiperfibersolutions.com
Fine Aggregate	Concrete Sand	Bozeman Block Brick and Tile	-	sales@bozemanbrick.com

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Mountains & Minds

Mixing and Placing Procedures

The Montana UHPC shall be mixed with a high-shear horizontal mortar mixer similar to one shown in Figure 1. It should be noted that two IMER Mortarman 360 mixers will be available to the contractor to use for the trial batches, mockup, and actual bridge application. These mixers are currently stored by the MSU Civil Engineering Department in Bozeman.

The mixing procedure for the Montana UHPC is as follows:

- Combine fine aggregate and silica fume. Mix for 5 minutes on low speed.
- Add portland cement and fly ash to mixer. Mix for 5 minutes on low speed.
- Combine water and HRWR in separate container and mix thoroughly.
- Add water and HRWR to mixer. Mix on low speed until mix becomes fluid (typically around 3-6 minutes).
- Add steel fibers and mix for approximately 3 minutes after becoming fluid.

Upon completion of the procedure above, the self-consolidating UHPC should be placed as soon as possible, and UHPC left in the mixer should be continuously mixed on low until placed. It should be noted that although the capacity of the mixers is 12 ft^3, UHPC batches should not exceed 5 ft^3. In order to accommodate larger batch sizes, the two mixers may be used in unison if correctly timed.

Figure 1: IMER Mortarman 360 mixer

References

1. Berry, M., R. Snidarich, and C. Wood, *Development of Non-Proprietary Ultra-High Performance Concrete*. 2017, Montana Department of Transportation.

2. Scherr, R., *Feasibility of Non-Proprietary Ultra-High Performance Concrete (UHPC) for Use in Highway Bridges in Montana: Phase II Field Application*, in *Civil Engineering*. 2020, Montana State University.

Task 3 – Bridge Construction and Related Activities

- Assist the contractor during trial batches… possibly fine tune mix design and refine process
- Assist in specimen mockup

Task 3 – Bridge Construction and Related Activities

Task 4 – Monitor Bridge Performance

- Continue testing strengths over time
- Inspecting bridge and documenting any potential signs of damage
- Comparing to control structure that did not use UHPC… Deep Creek Structures

Task 5 – Analysis of Results and Reporting

Deliverables

- Kick-off meeting and subsequent notes.
- 7 quarterly progress reports.
- 3-task reports (Tasks 1-3).
- Final Report.
- Final presentation and webinar.
- Project summary report.
- Implementation report.
- Performance measures report.
- Project Poster.

Schedule

Task/Milestone	Quarter (after start of work)							
	1	2	3	4	5	6	7	8
Task 0: Project Management	X	X	X	X	X	X	X	X
Task 1: Literature Review	X	X	X	X	X	X	X	X
Task 2: Close Research Gaps	X	X	X					
Task 3: Bridge Construction and Related Activities		X	X	X				
Task 4: Monitoring Bridge Performance				X	X	X	X	
Task 5: Analysis of Results and Reporting						X	X	X